PAPER

ITU Recommendations Regarding Propagation Effects on Mobile Satellite Links

F. Davarian
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, CA 91109. USA
Phone: 818-3544S20 FAX: 818-393-0096

ABSTRACT

To predict the effect of radiowave propagation on mobile satellite links, the International Telecommun ication Union (ITU) offers three recommendations. These recommendations have been developed by the participants of ITU Study Groups to enable service planners and design engineers of mobile satellite systems to characterize the mobile satellite link. This paper briefly reviews the structure of the 1"1'[1, its Study Groups, and its contributions to propagation modeling. The silo]-[collIil]:',s" of some of these models are examined and means to overcome them have been pointed out. The protocol for participation in ITU Study Groups is very 1)1iefly discussed.

INTRODUCTION

Anomalies rising from radiowave propagation in mobile satellite links can significantly limit the performance of a telecommunication system. Consequently, system planners strive for the prediction of propagation effects to reduce the risk associated with mobile communications. To assess the mobile satellite channel, major propagation experiments were first launched in the eighties with continuing work to date. Past efforts have resulted in a number of prediction models, enabling system engineers to evaluate the propagation channel in mobile satellite systems.

For the users of" propagation data, there are two major sources of information, NASA Reference Publications 1274 [1] and 1'1'(1- R recommendations. In this paper the latter source will be examined.

INTERNATIONAL TELECOMMUNICATION UNION

ITU is an intergovernmental organization that any sovereign state may become a member of. The member states, usually represented by their telecommunication agencies, are constitutional members with certain obligations and rights. These members pay for the expenses of the ITU and vote for the changes in the structure and the charter of the union. Other organizations, such as service providers, manufacturers, and scientific institutes, may be admitted through their national administrations to certain ITU activities but cannot vote.

The objectives of the ITU are as follows:

- maintain and extend international cooperation for improvement and rational use of telecommunications;
- promote the development of technical facilities and their most efficient operation with a view to improve the efficiency of telecommunication services and increase their usefulness to the public;
- harmonize telecommunication-related efforts of member nations.

The ITU achieves its goals via three functions: 1) standardization of telecommunications, 2) regulation of radio communications, and 3) development of telecommunications. These functions are carried out by the three Sectors of Telecommunication Standardization, Radiocommunication, and Development. Each Sector is headed by a director, and the union is headed by its secretary general, who is the legal representative of the ITU.

Figure 1 shows the structure of the ITU. As shown in Figure 1, the plenipotentiary conference is the ultimate policy-making body of the union. Since propagation work is conducted in the Radiocommunication Sector, the next section will examine this sector of the ITU.

ITU RADIOCOMMUNICATION SECTOR

ITU Radiocommunication Sector (ITU-R) deals with matters concerning radio communications, including the regulation of radio communications. Technical work is performed in Study Groups. Each Study Group deals with a specific area of Radiocommunication (propagation, interference, spectrum sharing, mobile communications, broadcasting, and many more). The products of Study Groups are ITU-R Recommendations. These recommendations are tools that can be used for design, specification, and calculation of telecommunication systems and system parameters.

In most countries active in 1'1'[1- 1<, a national ITU-R committee has been established. The 11. S, National Committee of the ITU-R functions as a federal advisory committee to the Department of State. It coordinates and reviews the submissions made by the United States to the meetings of ITU-R. Study Group members arc delegates sent by their administrations. Other organizations can also participate by sending their experts as participants if their organization has been admitted by their 1'1'(1- R National Committee. In the United States, the National Committee membership is open to everyone with a knowledge and interest in telecommunication matters. A written request or application to the particular U.S. Study Group chairperson is sufficient to establish membership.

A Study Group's agenda usually includes a complex set of issues. Therefore, each Study Group is divided into working parties, each of which attends to a specific area of work. Such working parties may further split into Task Groups, Focus Teams, Ad Hoc Groups, and so on.

Propagation is the purview of Study Group 3, and presently it consists of four Working Parties. Issues related to mobile satellite propagation are studied by Working Party M, chaired by Mr. Martin 11:1111. The 11. S. Study Group 3 delegation is chaired by Mr. 1 ldon Haakinson[2].

1'1'[1-1{ RECOMMENDATIONS FOR '1'1 IE PREDICTION OF PROPAGATION EFFECTS ON MOBILE SATELLITE LINKS

ITU - R offers three recommendations for the prediction of propagation effects in maritime, land, and aeronautical mobile satellite links. These recommendations are numbered 680, 68 I, and 682, respectively.

Recommendation 680

This recommendation deals with propagation effects on maritime mobile satellite links, and it consists of four areas:

- Tropospheric effects
- Ionospheric effects
- Fading due to sea reflection
- Interference from adjacent satellite systems

[1] Mr. Hall's address: Rutherford Appleton 1 aboratory, Chilton, Didcot, OXON OX11 0QX, UK
[2] Mr. Haakinson's address: 1'1'S, U.S. Department of Commerce, 325 Broadway, Boulder, CO 80303, USA

The Tropospheric Effects Section refers the user to Recommendation 618 of the ITU-R. The Ionospheric Section discusses scintillation and Faraday rotation, and a reference is made. to Recommendation 531. Topics such as fade depth, fade duration, and spectrum spreading due to multi path are discussed in the Sea Reflection Section. The models provided in this section are valid for frequencies 1- 2 GHz. Finally a method for calculating signal to interference power ratio in multiple satellite systems is given in the last section.

Recommendation 681

The main contribution of' Recommendation 681 is in providing five important prediction methods for land mobile satellite applications:

1. Empirical roadside shadowing
2. Attenuation frequency scaling
3. Fade duration distribution
4. Non-fade duration distribution
5. Fading due to multipath

All the above models have been empirically derived. The first model enables the user 10 predict the effect of roadside tree shadowing on the mobile satellite link. The model accepts path elevation angle and percentage of link availability as input parameters and outputs fade depth. This model is valid for the 1.5 GHz frequency.

The second model provides a simple equation for extending the range of the Roadside Shadowing Mode] to 0.8- 2..7 GHz. The input to this mode] is fade depth at frequency f_1, and the output is fade depth at frequency f_2, at the same probability level.

The third model provides a method of calculating fade duration statistics in land mobile satellite systems. This method applies only to a 5-dB fade threshold and cases of moderate to extreme shadowing. Although measurements have shown a moderate dependence on elevation angle, no dependence on elevation angle is given in this model. The fourth model provides an estimate of non-fade statistics, again restricted to a 5-dB fade threshold.

The fifth model includes two methods of predicting fading due to multipath, one in a mountain environment and the other in a roadside tree environment. Clear line of site is assumed in both these methods.

All five of the models of Recommendation 681 are plagued with limited experimental data and the difficulty of adequately describing the mobile terminal environment. These models will be refined in the future as more measurements become available.

Another important shortcoming of Recommendation 681 is that it does not sufficiently treat non-geostationary applications. The above models were developed using data from geostationary spacecraft. Hence subtleties such as dependence on elevation angle, which is an important parameter in non-geostationary systems, are not treated adequately. Study Group 3 members are currently working toward the improvement and expansion of Recommendation 681 models. It is expected that the following enhancements will be provided in the near future:

- A rigorous description of the environment
- Expanded range of model applicability (frequency, elevation angle, fade value, and percentage)
- Models valid for all orbital configurations (GEO, LEO, HEO, and MEO)
- Diversity models (satellite diversity, antenna diversity, etc.)

Recommendation 682

This recommendation consists mainly of prediction models and data on the effect of ground reflections in aeronautical links. Fade statistics due to sea reflections as a function of the path elevation angle can be computed. Also coherence Bandwidth as a function of aircraft altitude is given for low elevation angles. Data are also provided on the effect of land reflections. The data provided in this Recommendation have been taken at frequencies between 1 and 2 GHz.

CONTRIBUTIONS TO STUDY GROUP 3

Study Group 3 solicits contributions in the form of input documents from its members. These input documents may propose modifications and amendments to the existing Recommendations, propose new Recommendations, or may provide signal measurements (propagation data). The subject matter of the input documents is loosely confined to Study programs established by study Group 3 in response to questions posed by Radio Conferences, the Study Group itself, or other Study Groups.

For the purposes of model development and testing, Study Group 3 maintains a data bank of propagation measurements. As mentioned earlier, Recommendations 680, 681, and 682 have notable shortcomings due to the scarcity of data. Therefore, it is very important that this Data Bank is regularly supplied with new data to allow the enhancement of mobile satellite models. Study Group 3 has developed a simple format for supplying data to its Data Bank. For every study area, a single-page table is available for entering data. For example, land mobile satellite data (Recommendation 681) are provided using the table shown in Figure 2.

Each table is looked after by a volunteer table keeper. For example the author of this paper maintains the table shown in Figure 2. The Data Bank, which is the collection of all the tables in an electronic form, has a volunteer custodian, Mr. Bertram Arbesser Rastburg of the European Space Agency. Supplying data to Study Group 3 is, therefore, very simple. A table is filled out and provided to the Study Group as an input document. The table keeper of the supplied information will review the data for validity and clarity and will enter them in the data base. As a matter of courtesy, it is recommended that an electronic version of the table is also provided so that the table keeper is relieved from key punching the information into the computer.

Blank copies of Study Group 3 data tables can be obtained from the Radiocommunication Bureau in Geneva by sending a message to Mr. Kevin Hughes, counsellor (e-mail: kevin.hughes@itu.arcom.ch). Mr. Hughes can also provide the Data Bank.

ACKNOWLEDGMENT

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REFERENCES

1. J. Goldhirsh and W. Vogel, *Propagation Effects for Land Mobile Satellite Systems: Overview of Experimental and Modeling Results*, NASA Reference Publication 1274, Feb. 1992.

2. *1992 CCIR Recommendations, RPN Series, Propagation in Non-Ionized Media*, ITU, Geneva, Switzerland, Oct. 1992.

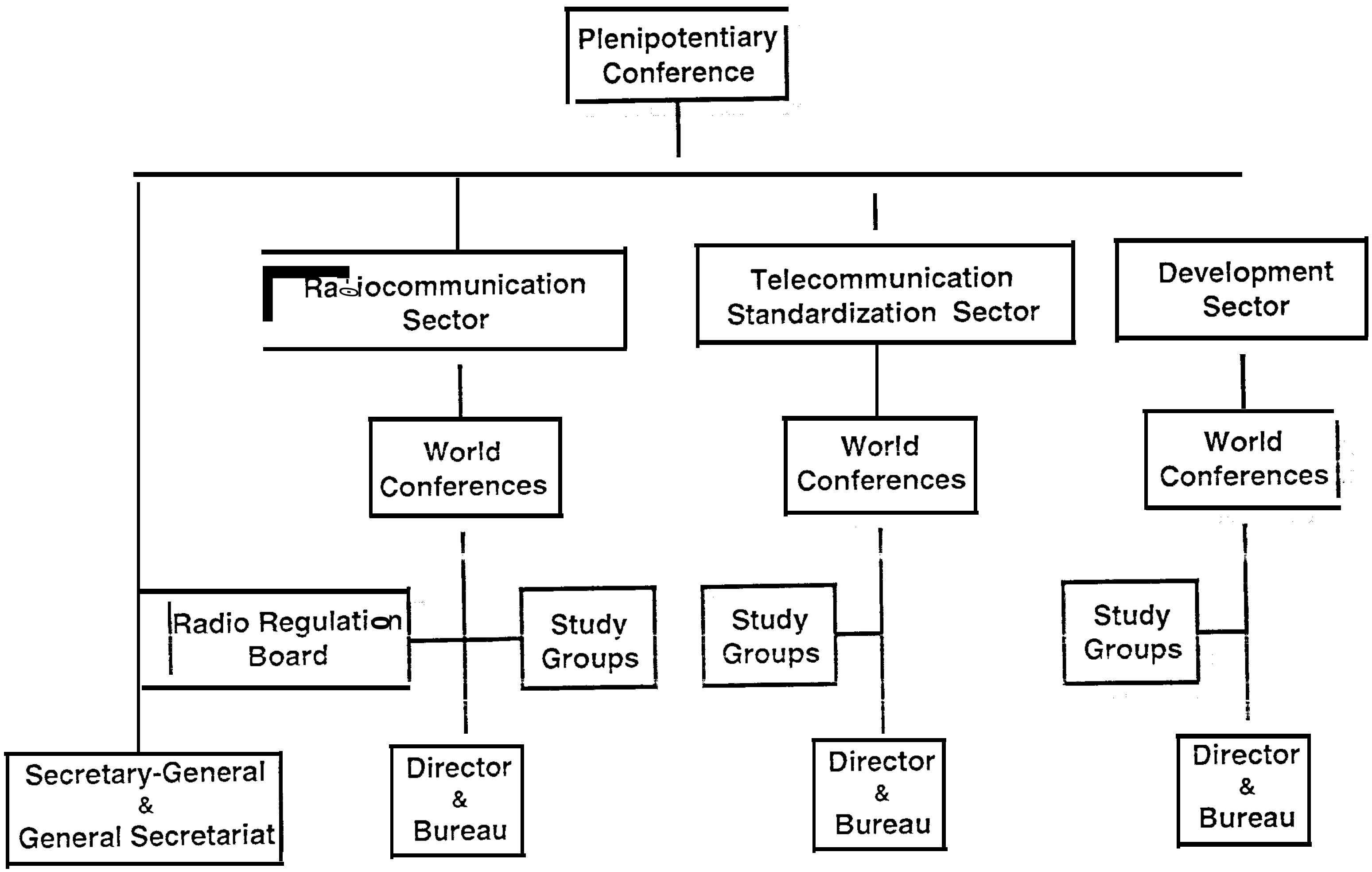

Figure 1. The Organizational Structure of the International Telecommunications Union

Fig 2

Draft Revision Rec 311-6 Ott 1993 (5 C/TEMP/43-E Rev1)

TABLE VII-3 Narrow-band statistics of Jand-mobile satellite links

station number

TX frequency (GHz)

TX polarization (L/C)

TX polarization tilt φ_t (deg)

RX average elevation angle

RX CCIR rain zone

Signal ● OUr= (transmitter on i.e: Satellite, heli-copter, ● eroplane, balloon, tower

If satellite: satellite name

orbital position (deg) E

TX antenna gain towarda mobile (dBi)

Mobile ● tation

RX area name

RX country ([1])

RX average latitude (-90..+90)(deg)

RX average longitude (0..360) (deg)E

Average velocity of vehicle (km/h)

RX average altitude amsl h_{gr} (m)

RX antenna heightagh h_r (m)

RX antenna type

RX 3 dB beamwidth in Az Θ_{rAz} (deg)

RX 3 dB beamwidth in El Θ_{rEl} (deg)

RX antenna gain (dBi)

RX antenna diameter D(m)

RX radome (Y/N)

RX polarization (L/C)

RX polarization tilt φ_r (deg)

RX multipath reduction (Y/N)

RX dynamic range (dB)

RX minimum signal-to-noise ratio (dB)

RX integration time [s)

RX bandwidth (Hz)

Data sampling interval (s)

calibration interval (days)

Data resolution (dB)

Measurement: Exp Nr.

Start date (yyyy. mm. dd)

End data (yyyy. mm. dd)

Duration of measurement in this ● nvironment (h)

Season

Environment

Land mobile terrain type ([2])

Building type

Vegetation type

surface Condition (wet, dry, snow)

Table ●:
Fade depth (dB relative to LOS) exceeded
and XPD (dB) NOT exceeded for percentage of time

% time	0.1	1.0	5.0	10.0	30.0	50.0	90.0	99.0	99.9
A XPD	. .	. .	. .	. .	. .	. .	. .	. .	. .

able b:
Fade duration reported in seconds or meters (s/m)
Fade duration (s or m) NOT exceeded for percentage of locations at given fade levels (sec)

% Loc	0.1	1.0	5.0	10.0	30.0	50.0	90.0	99.0	99.9
0 dB 2 dB 5 dB 10 dB									

References:

Comments:
([1]) See S 6.1 for list of country codes.
([2]) Environment types for land mobile: DU: dense urban, UR: urban, SW: suburban, RU: rural, WD: wooded, OP: open, HI: hilly, MO: mountainous, WA: water.

station number

TX frequency (GHz)

Tx polarization (L/C)

TX polarization tilt φ_p (deg)

RX average elevation angle

RX CCIR rain zone

Signal source (transmitter on i.e: Satellite, heli-copter, aeroplane, balloon, tower

If satellite: satellite name

orbital position (deg) E

TX antenna gain towards mobile (dBi)

Mobile station

RX area name

RX country ([1])

RX average latitude (-90. .+90) (deg)

RX average longitude (0. .360) (deg) E

Average velocity of vehicle (km/h)

RX average altitude amsl h_{gr} (m)

RX antenna height ag h_r (m)

RX antenna type

RX 3 dB beamwidth in Az Θ_{rAz} (deg)

RX 3 dB beamwidth in El Θ_{rEl} (deg)

RX antenna gain (dBi)

RX antenna diameter D (m)

RX radome (Y/N)

RX polarization (L/C)

RX polarization tilt φ_p (deg)

RX multipath reduction (Y/N)

RX dynamic range (dB)

RX minimum signal-to-noise ratio (dB)

RX integration time (s)

RX bandwidth (Hz)

Data sampling interval (s)

Calibration interval (days)

Data resolution (dB)

Measurement : Exp Nr .

Start date (yyyy.mm.dd)

End date (yyyy. mm. dd)

Duration of measurement in this environment (h)

Season

Environment

Land mobile terrain type ([2])

Building type

Vegetation type

Surface Condition (wet, dry, snow)

Table a:
Fade depth (dB relative to LOS) exceeded
and XPD (dB) NOT exceeded for percentage of time

% time	0.1	1.0	5.0	10.0	30.0	50.0	90.0	99.0	99.9
A	.	.	.	.	.	.	.	.	.
XPD	.	.	.	.	.	.	.	.	.

Table b :
Fade duration reported in seconds or meters (s/m)
Fade duration (s or m) NOT exceeded for percentage of locations at given fade levels (see)

% Loc	0.1	1.0	5.0	10.0	30.0	50.0	90.0	99.0	99.9
0 dB									
2 dB									
5 dB									
10 dB									

References :

Comments :
([1]) See § 6.1 for list of country codes.
([2]) Environment types for land mobile: DU: dense urban, UR: urban, SU: suburban, RU: rural, WD: wooded, OP: open, HI: hilly, MO: mountainous, WA: water.

Figure 2. Data Table for Land Mobile Satellite Links (narrow band statistics)